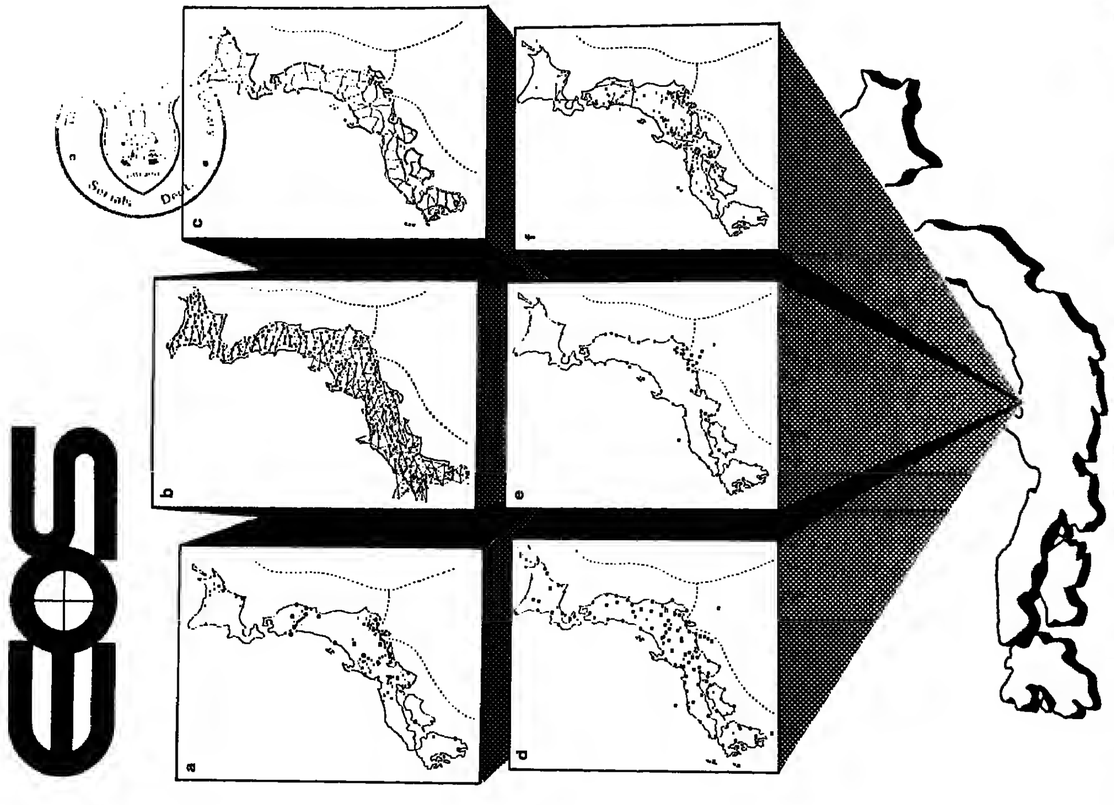


EOS, TRANSACTIONS, AMERICAN GEOPHYSICAL UNION VOL. 62, NO. 32, PAGES 617-824 AUGUST 11, 1981

Physical Properties of Rocks

6110 Elasticity, fracture, and flow
SEISMIC VELOCITIES AND ELECTRICAL RESISTIVITY OF RECENT VOLCANICS AND THEIR DEPENDENCE ON POROSITY, SATURATION, AND WATER SATURATION
See 6180 Magnetic and electrical properties
See 6180 Thermal properties
A. M. Ibrahim (Formerly Institute of Earth and Planetary Physics, University of Alberta; presently Geophysics Institute, University of Alaska, Fairbanks, AK 99701) George V. Keller

Variations of P-wave velocities and electrical resistivities of several suites of water-saturated recent volcanics was investigated. Both P-velocities and resistivities exhibited strong dependence on porosity. Sensitivity was also dependent upon degree of water saturation and temperature. P-wave velocities, while showing a strong dependence on porosity, appear to be independent of water saturation and temperature. Volcanics, in general, exhibit higher resistivities compared to other igneous rocks and sediments. Ilmenite tuesitesy of Pleistocene basalts is anomalously low, probably due to higher content of disseminated iron. Pyroclastics and volcanic breccia, on the other hand, exhibit higher resistivities in relation to lime-grained breccia.
GEOPHYSICS, Vol. 45, no. 10

6110 Elasticity, fracture, and flow
THE PRESSURE AND TEMPERATURE DEPENDENCE OF THE ELASTIC PROPERTIES OF POLYCRYSTAL MAGNESIOWUSTITE
L. Burnett and S. Graham (Department of Geosciences and Materials Research Laboratory, Pennsylvania State University, University Park, Pennsylvania, 16802)

The compressional and shear wave velocities in a series of polycrystal samples of magnesiowustite ($Mg_xFe_{1-x}O$) have been measured using the pulse superposition method. Each specimen was characterized in terms of composition, stoichiometry, and porosity by chemical and microprobe analysis, and by X-ray diffraction. In addition, the measurements of velocity in three perpendicular directions has determined that the individual specimens were isotropic to within 1%. The application of empirical corrections to account for the effects of non-stoichiometry and porosity has allowed the determination of the intrinsic elastic properties for the single stoichiometric $Mg_xFe_{1-x}O$ solid solution series. For materials for $Mg/(Mg+Fe) = 1.00$ to 0.64 it is found that consistent with previous determinations of these properties from stoichiometric specimens, in the case of Mg ($0 \leq Mg/(Mg+Fe) \leq 1$) the adiabatic bulk modulus K_S and shear modulus G decrease linearly with increasing Mg content, but by steep enough slopes that magnesiowustite of the deficient stoichiometric composition has a significantly greater bulk modulus than stoichiometric MgO. The increasing number of vacancy carriers toward the Fe-rich end member rationalizes both decreasing bulk modulus and anomalously high values of C_{44}/C_{11}. However, when corrections are applied for the non-stoichiometric effects, the elastic properties of the $(Mg,Fe)O$ solid solution series behave according to the linear combination relation proposed by Hill (1963) and Watson et al (1979).
J. Geophys. Res., Red, Paper 1B1194

6110 Elasticity, fracture, and flow
FAKING IN CLAST GARNETS AS AN INDICATOR OF LATE BRITTLE DEFORMATION AT COLE MOUNTAIN, WARREN COUNTY, N.Y.
A. J. Valentino (Department of Geological Sciences, Lehigh University, Bethlehem, PA 18015) C. B. Sclar

The Barton garnet deposit contains large garnet crystals (2.5–75 cm) disseminated through a gabbro-derived garnet amphibolite. These crystals are characterized by two sets of parting planes which intersect at about 80° and have a constant attitude throughout the amphibolite. The results of X-ray diffraction studies on the parting planes of the garnet crystals by the back-reflection Laue method and by X-ray diffractometry show that the parting-plane sets are not crystallographically controlled by the lattice of the garnet and that the garnets are not oriented in the amphibolite. Each parting set in the gibbsite garnets and its corresponding parallel joint set in the amphibolite matrix are interpreted as brittle fractures which developed in response to a dilatant tectonic episode. (Garnet, fracture).
Geophys. Res. Lett., Paper 1L1112

Seismology

6940 Phenomena related to earthquake prediction
INTERPRETATION OF CHANGES IN WATER LEVEL ACCOMPANYING FAULT CREEP AND IMPLICATIONS FOR EARTHQUAKE PREDICTION
R. L. Wesson (U.S. Geological Survey, Reston, Virginia 22092)

Quantitative calculations for the effect of a fault creep event on observations of changes in water level in wells provide an approach to the tectonic interpretation of these phenomena. For the post-pressure field associated with an idealized creep event having an exponential displacement vs. time curve, and analysis of suppression has been obtained in terms of responsivity-integral functions. The pore pressure vs. time curves for observation points near the fault are pulselike; a sharp pressure increase (or decrease depending on the direction of propagation) is followed by some gradual decay to the normal level after the creep event. The time function of the water-level change may be obtained by applying the filter defined by A. G. Johnson and others to determine the influences of atmospheric pressure on water level; to the analytic pore pressure vs. time curves. The resulting (or decreased) and then a very gradual return to normal. The results of this analysis model do not reproduce the step-like changes in water level observed by Johnson and others. If the procedure used to obtain the water level from the pore pressure is correct, these results suggest that step-like changes in water level are not produced by smoothly propagating creep events, but by creep events that propagate discontinuously, by changes in the hydropropagation of the region around the well, or by some other mechanism.

In addition, simplistic calculations show that significant pressure-field variations and water-level changes near the surface may be expected to accompany a propagating creep event on a buried fault. Water-level changes of as much as several meters may be expected at the surface for a creep event having a dislocation amplitude of 1 m at a point-infinite dislocation surface extending downward from a depth of 10 km and propagating horizontally at a rate of 10 km/day. The maximum near-surface effect should be observed at a horizontal distance from the fault about equal to the depth of the top of the dislocation surface. These results are consistent with the observations made in China of large water-level changes preceding large earthquakes, if some sort of seismic creep event at depth precedes those earthquakes.
J. Geophys. Res., Red, Paper 1B1102

6950 Seismic Sources
REGIONAL RELATIONSHIPS AMONG EARTHQUAKE MAGNITUDE SCALES
H. H. Chung and D. L. Bernreuter (Lawrence Livermore National Laboratory, University of California, P. O. Box 808, L-95, Livermore, California 94550

Various magnitude scales commonly used and the interrelationships among them are reviewed. It is shown that problems exist with all of the magnitude scales being used in the United States. When using regional catalogs, for example, it is often necessary to determine how the reported magnitudes were determined. Often such information is not available, although the potential errors are quite large.

Both the M_S and m_b scales were designed to be universal scales. However, both M_S and m_b magnitudes are often determined beyond the applicable range of the equations used to define the two scales. Furthermore, the M_S magnitudes are not generally available for materials to small earthquakes in most earthquake catalogs. The m_b magnitudes are more generally available than M_S values; however, there is also much greater variation in the way m_b is determined. In particular, a significant change in the m_b scale occurred in the early 1960's when the WWSSN was established. This change in instrumentation used to determine m_b values had a significant effect on estimated magnitudes (post-1960 values are lower) and the saturation level of the m_b scale. The older, longer-period instruments recorded larger m_b magnitudes than can be recorded with the the WWSSN instruments. In addition, great care must be taken when selecting the m_b magnitudes of western U.S. earthquakes, because the values are often in considerable error due to the fact that they were determined at distances less than 25° and were not properly corrected for attenuation in the upper mantle or asthenosphere.

The seismic body-wave magnitude m_b of an earthquake is strongly effected by regional variations in the Q structure, composition, and physical state within the earth. Therefore, because of differences in attenuation of P-waves between the western and eastern United States, a regional m_b magnitude is obtained which, depending on where the earthquake occurs and where the P-waves are recorded, can lead to magnitude errors as large as one-half unit. There is also a significant difference between the m_b and M_S values for earthquakes in the western United States. An empirical link between the m_b of an eastern U.S. earthquake and the M_S or an equivalent western earthquake is given by $M_S = 0.57 + 0.92(m_b)_{East}$. This result is important when considering the seismic hazard in both the two regions and for choosing a set of regional western U.S. earthquake records to represent eastern earthquakes.
Rev. Geophys. Space Phys., Paper 1R1007

Editorial

Membership Committee

One of the seven standing committees of the Union is called the membership Committee. It functions under the ex-officio chairmanship of the president-elect as an oversight committee on matters of broad concern to members but not within the specific purview of any of the other six committees. The Membership Committee has three such matters under consideration: AGU's sectional organization, the history of geophysics, and the conduct of Chapman conferences.

First, there appears to be a widespread feeling that some features of our sectional organization have become awkward and perhaps obsolete. This problem is both chronic and welcome because of the cross-disciplinary nature of the Union and the progressive evolution of new relationships among disciplines. One question is whether the name and organization of the Solar-Planetary Relationships Section are adequate to represent its evolving subject matter and to capture the loyalties of research workers. An active and relatively clear attempt to address part of this question is the proposal that SPR's Aeronomy Division and the Meteorology Section be combined to form a new Atmospheric Science Section.

Another organization question is whether the diverse subject matter of the Planetology Section might be more effectively represented if dispersed among the traditional section on geodesy, tectonophysics, meteorology (or atmospheric science), etc. It is the maturing of planetology that suggests its dispersion into the other sections; in addition, such a realignment may make AGU more attractive relative to the Division for Planetary Sciences of the American Astronomical Society (DPS/AAS). DPS/AAS activities parallel those of our Planetology Section to a considerable degree, but they do not enjoy the interplay with the relevant geosciences that is afforded by the meetings and journals of the AGU.

To take effect, any proposed change in sections must be endorsed by the Committee on Statutes and Bylaws and then approved by the Council as an amendment to the By-laws.

Second, the history of geophysics is a matter of increasing interest; at AGU's Spring Meeting, two sessions of invited papers were devoted to the subject. To explore ways of fostering this interest, the president is appointing a special Committee on the History of Geophysics to make a report to the Council in December 1981.

Third, the conduct of Chapman conferences has been largely entrepreneurial, sometimes with little help from the headquarters staff. We favor strong staff support; we believe that the Council will also favor such support if the annual number of topical conferences and their registration fees make such functions self supporting. A move in this direction may serve to capture a diversity of topical conferences and serve the membership better by integrating such conferences into the Union.

We solicit your comments on the above matters and on any other questions that you judge to be of general concern and not within the cognizance of other committees. The next meeting of the Membership Committee will be in early autumn.

James A. Van Allen, *Chairman*
L. Thomas Aldrich
Clarence R. Allen
Helmut E. Landsberg
Worth D. Nowlin, Jr.
Paul H. Serson
M. Gordon Wolman

Hydrologic Effects of Mount St. Helens' 1980 Eruptions

M. F. Meier, P. J. Carpenter, and R. J. Janda

U.S. Geological Survey
Tacoma, Washington

The May 18, 1980, eruption of Mount St. Helens caused an immediate destruction of life and property and profoundly changed the local environment. Hydrologic effects of the event persist to this day and may have additional drastic impacts on property and, perhaps, life in the years ahead. The most serious and potentially persistent hydrologic problem is the sedimentation in the Toutle and Cowlitz river systems initiated by volcanically generated mudflows and aggravated by massive erosion in the devastated area. This sedimentation has drastically reduced the carrying capacity of these streams. Flood flows this winter and spring, whether caused by rainfall, snowmelt, outbreaks from debris-dammed lakes, or by volcanically induced snowmelt, may not be contained within river channels. Ash deposits and developing drainage systems provide a continuing source of sediment flow. Destruction of forests and burial of the forest litter under ash has changed the infiltration characteristics of drainage basins near the mountain.

Mudflows coursed down all major drainages on Mount St. Helens during the cataclysmic May 18, 1980, eruption. Several did not travel beyond the base of the mountain. However, mudflows from the east side of the mountain flowed into Swift Reservoir, and a major flood traveled down the South Fork Toutle, Toutle, and Cowlitz rivers. Later in the day the most disastrous mudflow flowed down the North Fork Toutle and Toutle rivers and into the Cowlitz and Columbia rivers.

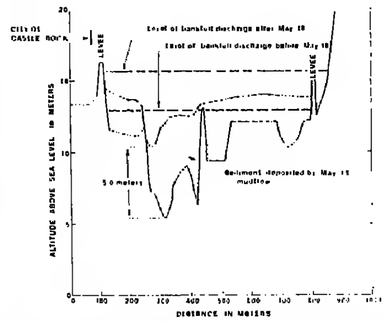
Mindy Brugman (see information contacts below) estimates that about 5–10 m of snow and ice was removed by hot ash flows from the Nelson, Ape, and Shoestring glacier areas on the east slope during the early phase of the May 18 eruption. This produced about 4 to 7×10^8 m^3 of liquid water, causing major mudflows along the Smith and Pine creeks and the Muddy River. Although these mudflows surged downvalley at depths of up to 20 m, the thickness of scour or deposition was generally a meter or less, according to Holly Mortenson. About 14×10^8 m^3 of this mud was deposited in Swift Reservoir (22 km downstream from the mountain) during the period 9–12 A.M., with a peak inflow rate exceeding 1700 m^3/s, according to John Cummens. The geometry of the resulting deposits and scour lines suggests that peak mudflow velocities locally exceeded 30 m/s (100 km/h).

Hot ash flows removed an estimated 5 to 8×10^8 m^3 of snow and ice from Toutle and Telus glaciers on the west slope, in the headwaters of the South Fork Toutle River. John Cummens reports that by 8:50 A.M. a flood of water, trees, and mud was passing a point 7 km downstream from the mountain on the South Fork Toutle River. This flood traversed the next 34 km at an average speed of 7.2 m/s (26 km/h) but locally moved as fast as 30 m/s (100 km/h). By 1:30 P.M. the flow had progressed into the Cowlitz River at Castle Rock (83 km from the source), and by 5:00 P.M. it had crested at Longview near the junction of the Cowlitz and the Columbia rivers (111 km from the source). At the Silver Lake gaging station on the Toutle River the gage height exceeded by 0.3 m the previous flood of record (1220 m^3/s).

The most spectacular hydrologic consequence of the May 18 eruption (and probably the one with the greatest persisting hazard to men) was the flood and mudflow sequence that coursed down the North Fork Toutle, Toutle, and Cowlitz rivers. The cataclysmic avalanche, blast, and eruption, at 8:32 A.M., deposited a huge (2.5×10^9 m^3) pile of rock debris, ash, hot pyroclastic deposits, ice blocks, melted snow and ice, and organic materials in the upstream 18 km of the North Fork Toutle River valley. Mindy Brugman estimates that 70% (1.3×10^8 m^3) of the mountain's glacier ice volume was included, largely as melt water, in this debris pile. Additional water was probably supplied from Spirit Lake, which was raised 60 m, and perhaps other water was derived from within the volcano itself. Stability analyses of the cataclysmic landslide by Barry Voight suggest that failure required a fluid pressure equivalent to a liquid water head roughly 300 m over the entire failure surface. Thus virtually the entire avalanche mass was water saturated. Spectacular roofless phreatic eruptions took place along North Fork Toutle River valley as water and hot pyroclastic flows came into contact.

Surprisingly, no flood or mudflow of any consequence moved further down this drainage during the morning of the day of the eruption. Water from melting snow and ice, expelled during the eruption and ejected from compacting debris, collected and was trapped on the debris pile in ponds ranging up to 1 km in diameter. As the ponds grew in size they breached the unconsolidated material and moved downstream to be trapped again. This process continued throughout the morning with the increasing accumulation of hot, sediment-laden water.

At about 1:25 P.M. on May 18 an immense mudflow, estimated by Dick Janda to have a volume of the order of 8×10^7 m^3, moved downstream off debris pile and down the



Cross sections of the Cowlitz River near Castle Rock, Washington, before and after the May 18, 1980, eruption. Bankfull discharge is 2,150 m^3/s.

North Fork Toutle River. This mudflow devastated lumber camps, bridges, homes, and other buildings along the North Fork and the main stem of the Toutle River. According to John Cummans, the mudflow had the consistency of fresh mortar, with buildings and loaded logging trucks floating high, and it traveled to the mouth of the Toutle River at an average speed of only 2 m/s (7 km/h). However, superelevation of the mudflow at stream bends indicates that local velocities commonly were in the range of 7–8 m/s (25–30 km/h). At the Silver Lake gaging station on the Toutle River the gage height exceeded by 9.1 m the new record stage recorded 8 hours earlier from the South Fork mud-

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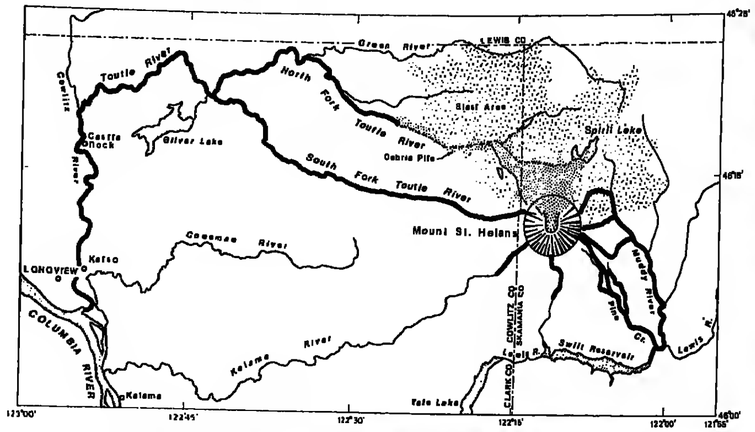
Cover. Hayloft of a two-story barn along the Cowlitz River south of Castle Rock, Washington, partially inundated by mudflow from Mount St. Helens. USGS photograph by Lyn Topinka. (see article on Mount St. Helens' beginning this page.)



Index map of Mount St. Helens area. Streams affected by major mudflows are indicated by heavy lines.

flow. In sleep reaches the mudflow caused channel erosion; in gentle reaches, channel and floodplain deposition.

This huge mudflow then progressed down the Cowlitz River, depositing about 2.5×10^7 m^3 of mud and debris in the channel and on the floodplain, and by the next morning had deposited more than 1.4×10^7 m^3 of debris in the Columbia River, blocking the passage of large ships between Portland, Oregon, and the Pacific Ocean. At the Cowlitz River gaging station at Castle Rock the streambed was raised about 5 m, drastically reducing the carrying capacity of the channel. According to Ron Lombard, the river stage just before the mudflow was 5.43 m, and the flow was 174 m^3/s; flood stage was considered to be 13.2 m, corresponding to a flow of 2150 m^3/s. On May 20, 2 days after the mudflow, the stage was 12.8 m, with flow of only 174 m^3/s. In spite of a major dredging operation the high discharges to be expected in winter because of rain or snowmelt may not be accommodated in the channel.

The massive sedimentation in the channel and on the floodplain of the Cowlitz River caused many hydrologic problems. Tributaries were dammed, and their flow collected in ponds adjacent to this river. Infiltration of this water and the reversed groundwater gradient from the raised streambed caused groundwater levels to rise, flooding septic tanks, drainfields, feed lots, and solid-waste disposal sites. Municipal water supplies were interrupted for hours, requiring diversion of industrial waters. Municipal sewer outfalls were plugged for days, requiring land disposal of wastes.

Since the eruption, logs and other organic materials trapped in the debris material have been 'cooking' and forming toxic polyphenolic compounds, some of which have found their way into the ponds forming behind the blockage. Similar compounds are being manufactured by prolific heterotrophic bacteria inhabiting these lakes and ponds in the blast zone. Jim Sedell reports that these lake and pond waters contain as many as 10^9 living cells per ml, mostly bacteria and blue-green algae. Breaching of these ponds could send these deleterious compounds downstream to the Cowlitz River.

Since May 18, several breakout floods have been generated from the hydrologically unstable debris pile. A pond, accumulating water from Castle and Merrits creeks, broke out on August 18, carving a 720-m-long channel in less than 1 hour before entering an impoundment near Elk Rock. This dam was overtopped and breached on August 27, releasing about 3×10^5 m^3 of water into the North Fork Toutle River. The resulting flood eroded 2.8×10^5 m^3 of material from the debris pile; of this 2.0×10^5 m^3 of material was deposited in the channel of the North Fork Toutle River, and much of the rest was moved downstream as far as the Cowlitz River, according to Mike Nolan and Phil Carpenter. A numerical dam-break model was used by Vern Schneider to predict the effects of the forthcoming breakout. The model predicted a flow at the Corps of Engineers dam of 5700 m^3/s, whereas the observed (estimated) flow was 4500 m^3/s. Similar or larger outbreaks may continue to occur for many months, if not years.

The fallout of volcanic ash has had varying hydrologic effects. Light ashfalls on the Bull Run watershed, Oregon, on March 30, May 25, May 28–June 2, and June 12–13, caused no significant changes in stream water quality, according to Michael Shultera and Daphne Clifton. John Klein reports that small streams to the east of Mount St. Helens showed pronounced but short-lived effects, such as increases in sulfate and chloride anions, suspended iron, and aluminum. Depression of pH was brief and minor. Heavy ashfall decreased soil permeability.

A study by Carolyn Driedger showed that ash thicker than ~25 mm deterred snowmelt but enhanced it when thinner than 25 mm. Maximum enhancement of the melt rate occurred at 2–5 mm, an increase of almost twice over ash-free conditions.

The transient response to major changes in the geometry of the remaining glaciers on Mount St. Helens is being studied by Mindy Brugmen. The removal of the area of Shoestring Glacier above 2400 m was followed within a month by a reduction of velocities near the terminus. The velocity continued to decrease everywhere on the glacier during the 1980 summer. A kinematic wave caused by the sudden decrease in ice flux would not be expected to reach the lower portions of Shoestring Glacier in less than 4 years. A dynamic response during the next decade may be observed on other glaciers around the mountain, such as Swift Glacier, which had a dramatic decrease in melting because of an insulating ash cover.

Several hydrologic hazards remain in the Toutle River valley, and these will plague the citizens living along it and the Cowlitz and Columbia rivers for years. Normal precipitation and snowmelt will move massive amounts of sediment downstream from the debris pile and from the deposited mudflows along the Toutle River system. The debris which avalanched into the North Fork Toutle River valley blocked the inflow of several tributary streams. Of these, two could form large ponds that could eventually breach, as could Spirit Lake, sending large amounts of water and sediment downstream to the Cowlitz River. Pyroclastic flows onto this coming winter's snow pack could also send floods of water and sediment downstream. If the sediment cannot be caught and removed from the Cowlitz River, the flood threat will be continuous. Various mitigation measures, including channel dredging, construction of retention structures, and seeding of vegetation, have been initiated, but their effectiveness remains to be demonstrated.

Information contacts: Mark F. Meier and Carolyn Driedger, U.S. Geological Survey, Project Office-Glaciology, 1201 Pacific Avenue, Suite 850, Tacoma, WA 88402.

Phil Carpenter, John Cummans, Ron Lombard, Holly Martenson, and John Klein, U.S. Geological Survey, 1201 Pacific Avenue, Suite 600, Tacoma, WA 88402.

Dick Jenda, U.S. Geological Survey, 301 E. McLaughlin, Vancouver, WA 88660.

Mindy Brugmen, Division of Geological and Planetary Sciences, California Institute of Technology, Pasadena, CA 81109.

Michael Shultera and Daphne Clifton, U.S. Geological Survey, 830 NE Holladay Street, P.O. Box 3202, Portland, OR 87208.

Barry Voight, Department of Geosciences, Room 333, Deike Building, Pennsylvania State University, University Park, PA 16802.

James Sedell, Forestry Sciences Library, 3200 Jefferson Way, Corvallis, OR 97331.

Forum

Mohr on the Minerals Bill

Your item on NMSA (National Minerals Security Act) [*Eos*, May 19, p. 487] makes depressing reading. According to Mr. Sentini: '. . . the hands of a few foreign nations [hold those minerals without which] we cannot build jet aircraft, weapons, or other military hardware vitally important to our national security.' The implication in the superlucious adjective 'foreign' is tangible. Those non-American nations are set up as being a threat; but a threat to what? To security in which there are several dubious ingredients, not least the means whereby what now needs guarding was itself secured? And, one can ask, to what extent does security form a solid-solution series with material aggrandizement when studied objectively?

What the proposed NMSA and Council on Minerals and Materials seem poised to achieve is yet further fraud and deception on the issues of public lands, and not forgetting remaining aboriginal American lands. A thousand Afghanistans have been fought over those lands in the past 200 years, and though the tenant is now well established as the landlord, his acquisitive appetite appears to be insatiable. Laws, treaties, and pledges signed, all are obstacles to be negotiated, renegotiated, and bypassed. Senators, congressmen, lawyers, tribal councils, and members are bought and sold for the sake of minerals and land.

So CONPASO strip the Navajo at Burnham, WEST do it at Black mesa, Exxon play with the Chippewas at Crandon, Kerr-McGee and friends scour northern New Mexico, the Air Force bestow missile sites on the Western Shoshone, the Lakota Sioux blindly read and reread the Black Hills treaty, which foundered on love of minerals.

How can there be security in a house when the family itself shows division, deception, and dishonesty? What this finite planet needs from its most powerful and wealthy nation is an example—not of acquisition at the expense of or for fear of others, but moral leadership and personal sacrifice. Otherwise security will remain as elusive to the United States as it was to wealthy, well-armed British landlords in 19th century Ireland.

Paul Mohr
Professor of Geology
University College Galway
Ireland

News

Ganymede: Cat's Cradle of the Ices

The Jovian satellite Ganymede is composed of ice and silicate minerals. According to a recent analysis (*Nature*, 292, 225–227, 1981) by French geochemists J. P. Poirier, C. Satin, and J. Peyronneau of the University of Paris, the ice forms of Ganymede may have undergone a complex pressure-temperature history. The mechanism proposed solid state convection of high-pressure phases of H_2O driven by heat from radioactive decay of U, Th, and K contained in Ganymede's 'hard rocks.' Poirier and his colleagues describe the geologic history of Ganymede as a passage of the ices, from Ice 1 to Ice 8, through the web of phase boundaries in pressure-temperature space.

Viscosity is the clue, it seems. Poirier et al. made visual observations with a ruby window, high-pressure apparatus positioned for viewing under a microscope. Tap water contained in the sample chamber was frozen directly to Ice 8 by the application of pressure alone, at room temperature. Poirier et al. observed the Ice 8 crystals growing, and then undergoing a creep-flow process over a period of 17 minutes or so, along a superimposed pressure gradient. The Ice 6 crystals were photographed and their positions noted by precise markers.

The study to determine the viscosity of Ice 8 under these conditions involved a number of assumptions. The pressure gradient was estimated on the basis of gradients determined in other (more viscous) materials. The relationship of the creep velocity to the viscous shear rate of Ice-8 was also estimated with a simple direct proportion as follows:

$$\eta(\dot{\gamma}) = \frac{\delta P(\dot{\gamma})}{\delta \dot{\gamma}} \frac{h}{4\dot{\gamma}r z(\dot{\gamma})}$$

where $\eta(\dot{\gamma})$ is the viscosity, a function of radial pressure gradient $\delta P(\dot{\gamma})$; h is the thickness; and $\dot{\gamma}rz(\dot{\gamma})$ is the viscous shear rate. The high-pressure viscosity of Ice 8 thus determined varies from 2.4×10^{13} to 1.4×10^{14} poises over the pressure range 1.08–1.22 GPa (at $T = (10°–16° C < \text{melting } T)$). Near the phase boundary of Ice 8 and Ice 7 the viscosity was extrapolated to the value of $\eta = 1.7 \times 10^{18}$ poises (at $T = (50° C < \text{melting } T)$).

The viscosities of the ices in the range below 10^{17} poises seem to be low enough for solid state convection in a process that would affect the heat flow and prevent melting and differentiation of the planet-satellite. The consequences for Ganymede include the possibility that no differentiation has occurred throughout its history. There is a balance in figuring the heat transfer, the possibilities of melting, the gravitational sinking of rock to form a core, and the formation of an Ice 8 mantle.

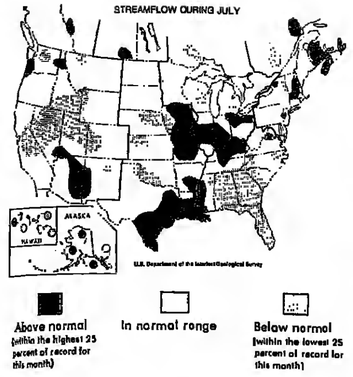
The Poirier team is aware of the dangers of oversimplifying a model process for planetary formation. They note that several factors, such as the rate of initial accretion of ice and rock, tidal dissipation, and high luminosity of Jupiter, could affect the balance and cause melting and differentiation. What can be concluded, if of course one believes the assumptions of the experiments and the assumptions of solid state convection, is that Ganymede had an evolution that included phase changes in Ice through at least Ice 8, and possibly Ice 8. The convective overturn of the ices would have affected the heat flow and thus the dynamics of formation. Ganymede consists of ice and rock in about equal proportions by mass, resulting in a dominant volume of the ices along its radius.—*PMB* ⊠

Improved National Water Outlook

The nation's water situation continued to improve during July in most of the country, although below-normal streamflow conditions persist in the Southeast and scattered parts of the central and western states, according to a month-end check by the U.S. Geological Survey.

USGS hydrologists said just slightly more than one fourth of the 181 key index stations reporting in July indicated well-below normal streamflow—within the lowest 25% of record. This is in contrast to previous months when one half to three fourths of the key index stations reported below-normal streamflow. Below-normal flows were reported in all or parts of 23 states, mostly in the Southeast, down from 27 states that reported low streamflow in June.

The Southeast remains hard hit by low-flow conditions, which extend along the coastal states from North Carolina south to Florida, and west to Alabama. All six index stations in Florida had well-below normal monthly flows for the third straight month, and two of the six stations established new monthly record low flows. In Alabama and Georgia, streamflows were in the lowest 25% of record, i.e., 75% of the time, flow will be equaled or exceeded at all eight index stations, and the four stations in Georgia set new record monthly lows for July.



As a general indication that this spring's drought conditions are lessening somewhat, the combined flow of the 'Big Five' rivers—Mississippi, Columbia, St. Lawrence, Missouri, and Ohio—averaged 880 billion gallons per day (bgd) during July, 25% above normal, the second straight month of above-normal flow after six months of below-normal conditions.

The Big Five rivers account for stream runoff in about half of the conterminous United States and provide a quick, useful check on the status of the nation's water resources.

Individual flows for the Big Five for July: Mississippi River near Vicksburg, Miss., 386 bgd, 31% above normal but 33% below June; Columbia River at The Dalles, Ore., 191 bgd, 10% above normal but 37% below last month; St. Lawrence River near Massena, N.Y., 170 bgd, 2% above normal and 4% above June; Missouri River at Hermann, Mo., 108 bgd, 107% above normal and 41% above last month; Ohio River at Louisville, Ky., 38 bgd, 38% above normal but 74% below June. (Photo credit: U.S. Geological Survey, Department of the Interior.) ⊠

Geophysicists

Norman H. Brooks, professor in the Department of Environmental and Civil Engineering at the California Institute of Technology, was elected a member of the National Academy of Sciences.

James Dooge has been appointed minister for foreign affairs of the Irish Republic. The professor of civil engineering at University College Dublin was named an AGU Fellow at the Spring Meeting in Baltimore.

C. Barry Raleigh, an AGU Fellow, has been appointed director of the Lamont-Doherty Geological Observatory of Columbia University, effective August 15. He was coordinator of the earthquake prediction program in the Office of Earthquake Studies at the USGS in Menlo Park. Raleigh succeeds *Neil Opdyke*, who has been interim director since January. Opdyke is now the chairman of the geology department at the University of Florida in Gainesville.

WOMEN ENLIST YOURSELVES

in the Third Edition of the

Roster of Women in the Geoscience Professions

The roster, published by the American Geological Institute, is open to all professional women employed in any aspect of geosciences.

Biographical forms can be obtained from AGU, 2000 Florida Avenue, N.W., Washington, D.C. 20009. Deadline for returning the forms is September 1.

New Publications

Metamorphic Petrology: Mineralogical, Field, and Tectonic Aspects, 2nd Ed.

F. J. Turner, McGraw-Hill, New York, xv + 524 pp., 1981, $28.50.

Reviewed by Akiho Miyashiro

F. J. Turner has published a large number of textbooks concerning petrology and petrography of igneous and metamorphic rocks that have contributed to the geological education throughout the world for the last 30 years. The book now under review is the latest of the series and is the second considerably rewritten edition of *Metamorphic Petrology: Mineralogical and Field Aspects*, which was published in 1968. It is noted that the term tectonic has been added to the subtitle.

This book is very comprehensive. It deals with almost all aspects of metamorphic petrology, ranging from thermodynamics, mineral parageneses, and synthetic experiments to geological and tectonic relations, even though discussion of individual aspects is not thorough. Probably a majority of those who teach metamorphic petrology in colleges and universities will look upon this as a well-balanced and convenient textbook.

Before Turner, the only book in metamorphic petrology giving so comprehensive a treatment had been Eskola's treatise of metamorphic rocks published as part of the book, *Die Entstehung der Gesteine* (1939). Turner's first textbook (published in 1948) was very similar to it. However, he gradually modernized his later books by incorporating an increasingly larger amount of new data and new interpretations. We can still recognize some vestiges of Eskola's framework of treatment in the present book, as Turner himself acknowledged.

Chapter 1 gives concise definitions of various categories of metamorphism and of metamorphic rocks and then briefly describes the most frequently cited metamorphic terranes of the world, such as the Scottish Highlands, the northern Appalachians, southern New Zealand, and Japan. Chapter 2 outlines basic ideas and principles of metamorphic petrology, starting from Charles Lyell through Grubenmann and Eskola to the phase rule and reaction kinetics.

Chapter 3 discusses the methods of determining metamorphic pressure and temperature based on synthetically determined stability curves and thermochemical calculations as well as on solid-solution and oxygen isotope geothermometers. Chapter 4 summarizes the synthetic data related to mineral parageneses in metapelites, siliceous dolomitic limestones, ultramafic rocks, and glaucophane schists. Chapter 5 deals with the methods of graphical representation of paragenetic relations: ACF, AKF, and Thompson's AFM diagrams. (More recently proposed diagrams for metapelites and metabasites are not treated.)

Chapter 6 gives a questionable classification of metamorphic facies into those of contact and of regional metamorphism. The latter are subdivided into two even more questionable categories: the facies of low grade (arranged in the order of increase in presumed depth from the zeolite through prehnite-pumpellyite and blueschist to greenschist facies) and those of high grade, which include the amphibolite, granulite, and eclogite facies. Coombs' lawsonite-albite-chlorite facies as well as Hashimoto's pumpellyite-actinolite facies is accepted in the low-grade category. Chapter 7 gives a description of some observed metamorphic facies series.

Chapters 8, 9, and 10 give rather detailed descriptions of individual metamorphic facies and areas where they are exposed. Chapter 11 summarizes the diversity of the observed P-T relations of regional metamorphism.

Frequently cited authors range from such old-timers as Goldschmidt, Eskola, Seki, and Fyfe, to some relatively young people who have published mainly in the last 10 years such as E. H. Brown, D. M. Carmichael, M. Frey, P. H. Thompson, and B. F. Windley.

I am afraid, however, that readers may not be satisfied by the treatment of the problems of paregenesis as exemplified by the following: J. B. Thompson's (1955) classical paper on the thermodynamic basis for the mineral facies concept is not cited at all. The mineralogical phase rule is all but ignored. Though Thompson's AFM projection is described, it is done only as a method of projection of a tetrahedron onto a plane and not in relation to the mineralogical phase rule. The important series of papers on the progressive changes of paregenetic relations of metapelites published by J. B. Thompson and A. B. Thompson in the middle 1970's is completely ignored.

Akiho Miyashiro is with the Department of Geological Sciences, State University of New York, Albany, New York.

Classified

SERVICES

STUDENT OPPORTUNITIES

Meetings

IAG Tokyo Meeting

Provisional registration forms for the general meeting of the International Association of Geodesy (IAG) are due in Japan by August 31. The meeting's second bulletin, including registration form, will be sent only to those who return the provisional form.

The meeting, scheduled for May 7–20, 1982, in Tokyo, will feature several symposia topics: geodetic problems in developing countries; geodesy for global geodynamics; recent crustal movements and phenomena associated with earthquakes and volcanism; high-precision gravity measurements; geoid determination and definition; refraction; marine geodesy, including sea gravimetry; space techniques; and geodetic applications of radio interferometry. Abstract deadlines are available from the organizing committee. In addition to the symposia, study tours will be conducted to Izu, Hakone, Kyoto, and Nara.

Official languages of the meeting are English and French. Simultaneous interpretations may be available between English and Japanese.

Send provisional registration forms to I. Nakagawa, deputy chairman of the local organizing committee, General IAG Meeting, Geophysical Institute, Kyoto University, Sakyo-ku, Kyoto 606, Japan. ✪

Radwastes and the Unsaturated Zone

The majority of hazardous and low-level radioactive waste that is placed in the subsurface is affected by the physical and chemical processes active in the unsaturated zone. A special session on the role of the unsaturated zone in radioactive and hazardous waste disposal will be held as part of AGU's Spring Meeting in Philadelphia on May 31–June 4, 1982. The symposium is sponsored by the AGU Committee on Water in the Unsaturated Zone.

The program will focus on the use of laboratory analysis, field observations, and numerical and analytical calculations. Possible topics include unsaturated-zone modeling, characterization of attenuation properties, field studies, and chemical reaction characterization.

Anyone interested in contributing a paper should submit an abstract in AGU format, by February 15, to James W. Mercer, GeoTrans, Inc., P.O. Box 2550, Reston, VA 22090. The abstract original must be sent directly to Meetings, AGU, 2000 Florida Avenue, N.W., Washington, D.C. 20009 by the Spring Meeting abstract deadline in early March. Additional information can be obtained by calling Mercer (703/435-4400), P.S.C. Rao (telephone: 904/392-1951), or I. Wendol Marine (telephone: 803/725-3469). ✪

AGU CHAPMAN CONFERENCE

RAINFALL RATES

April 27–29, 1982 Urbana, Illinois

Convenor: D. M. Hershfield

Sessions planned:

Atmospheric physics as related to rainfall processes.
Measurement: mass (tipping bucket), photoelectric, magnetic, and remote methods.
Models: physical, mathematical, and statistical.
Applications: point, area, quasihorizontal path, surface, troposphere, and stratosphere.

Call for papers published in *EOS*, July 14. Abstract deadline: December 21, 1981.

Gas Transfer at Water Surfaces

The International Symposium on Gas Transfer at Water Surfaces is slated for June 13–15, 1983, at Cornell University. Purpose of the symposium will be to summarize the state of the art of gas transfer processes at the air-water interface.

Disciplines to be touched upon include geochemistry, oceanography, meteorology, chemical engineering, physical chemistry, fluid mechanics and hydrology, and hydraulic and environmental engineering. Sponsors are Cornell University and AGU.

For additional information, contact W. H. Bruteaert, School of Civil and Environmental Engineering, Cornell University, Hollister Hall, Ithaca, NY 14853. ✪

Changes

The complete Geophysical Year list appeared in the July 21 *Eos*.

Solstice type indicates meetings sponsored or cosponsored by AGU.

1982

May 17–22 International Solar-Terrestrial Physics Symposium, previous listing of date of meeting was incorrect.

New Listings

1981

Sept. 9–13 Symposium and Workshop on Applications of Remote Sensing for Rice Production, Hyderabad, India. Sponsors, Institute for Atmospheric Optics and Remote Sensing, National Remote Sensing Agency, (A. Deepak, Institute for Atmospheric Optics and Remote Sensing, P.O. Box P, Hampton, VA 23666.)

Oct. 28–30 26th Annual Midwest Groundwater Conference, Bismarck, N. Dak. Sponsors, North Dakota State Water Commission, North Dakota District WRD-USGS, North Dakota Geological Survey, North Dakota WRRI. (D. Ripley, North Dakota State Water Commission, 900 E. Boulevard, Bismarck, ND 58501.)

Nov. 2–5 GSA Annual Meeting, Cincinnati, Ohio. (J. M. Latullppe, Meetings Department, GSA, P.O. Box 9140, Boulder, CO 80301.)

Nov. 9–11 Workshop on Comparisons Between Lunar Breccias and Soils and Their Meteoritic Analogs, Houston, Tex. Sponsor, Lunar and Planetary Institute. (P. Jones, Projects Manager, Lunar and Planetary Institute, 3303 NASA Road 1, Houston, TX 77058.).

1982

Jan. 13–15 National Radio Science Meeting, Boulder, Colo. Sponsors, U.S. National Committee for the International Union of Radio Science, IEEE. (U.S. National Committee for URSI, National Research Council, 2101 Constitution Avenue, N.W., Washington, DC 20418.)

1981 Midwest Meeting
Plan to Attend

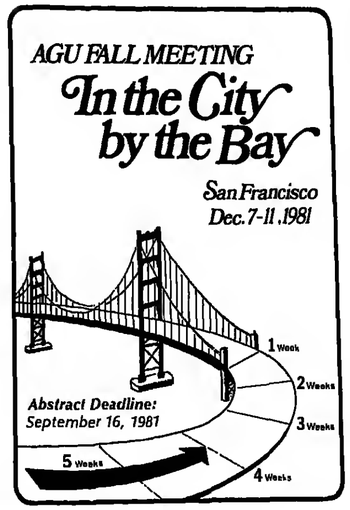
September 17–18
Minneapolis, Minnesota

Radisson Hotel (Rates: Single $34, Double $40, Triple $12.50 per person)

Special Sessions:

Thursday
- Mantle structure and dynamics
- Hydrology in the mid-continental U.S.

Friday
- Precambrian crustal evolution of the North American continent
- Sedimentary paleomagnetism: Geological history from the recent to the Precambrian
- Rock water interactions: Hydrothermal processes and metallo genesis



Ocean Sciences: AGU/ASLO Joint Meeting

February 16–19, 1982
San Antonio, Texas
Convenor: W. D. Nowlin, Jr., (AGU) and R. W. Eppley (ASLO)

Abstract Deadline: November 10, 1981

Special Sessions

Ocean Climate and Biological Productivity Connections
Overview of Large Oceanographic Projects
Biology and Physics of Gulf Stream Rings
Relations Between Biology and Circulation in the Gulf of Mexico
Geological Effects of Ocean Circulation
Anthropogenic Inputs to the Ocean: Diverse Points of View
Processes and Resources of the North Pacific Shelves
Small Lake Limnology
Marine and Freshwater Bioturbation
Ocean-River Interaction: Sedimentation and Chemistry
Particle Fluxes in the Water Column and Benthic Boundary Layer
Relations Between Mesoscale Physical and Biological Processes
Coastal Processes
Biological and Physical Measurement Techniques
Microscale Processes and Effects on Biota
Physics and Biology of Ice Edges
Physical, Chemical and Biological Processes in Large Lakes

Call for papers published in EOS, June 23.

AGU

Jaime Amorocho, for his contributions to nonlinear theory of hydrologic systems.

Richard John Anderle, for his contributions to understanding the earth's gravitational field.

Kinsey A. Anderson, for his contributions to experimental space physics.

F. H. Busse, for his contributions to nonlinear theory of fluid convection.

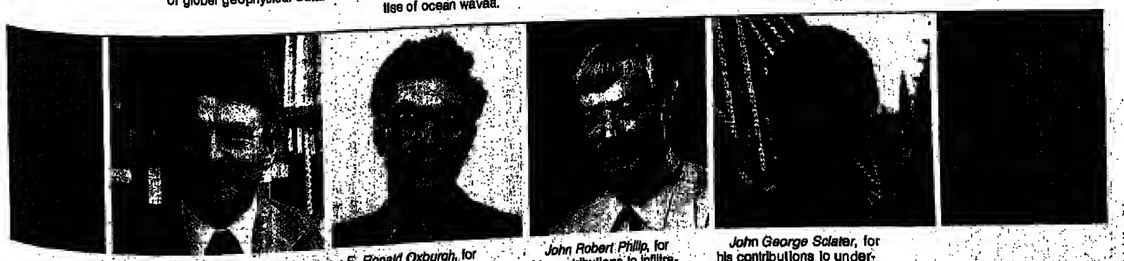
James C. I. Dooge, for his contributions to linear theory of hydrologic systems.

Virginia Lincoln, for her contributions to the organization and dissemination of global geophysical data.

Michael S. Longuet-Higgins, for his contributions to understanding the physical and stochastic properties of ocean waves.

Peter H. Molnar, for his contributions to the theory of plate tectonics.

Andrew F. Nagy, for his contributions to understanding the energetics and dynamics of planetary ionospheres.



Worth D. Nowlin, for his contributions to experimental oceanography.

E. Ronald Oxburgh, for his contributions to Earth tectonics and mantle convection.

John Robert Philip, for his contributions to infiltration and evaporation in hydrologic systems.

John George Solater, for his contributions to understanding evolution of the deep-sea floor.

GAP

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Aeronomy

0310 Absorption and scattering of radiation
DETECTION OF NIGHTTIME ATMOSPHERIC SCATTERING OF LUNAR UV RADIANCE BY THE NIMBUS IV BUV INSTRUMENT
D.G. Skaslnopoulos (NASA-Goddard Space Flight Center, Code 991, Greenbelt, Maryland 20771), S.G. Goldberg, A.D. McPeters, and J.H. Heath

Morphological studies of nighttime dark current data from the Nimbus 4 BUV experiment clearly indicate enhancements during periods of the full moon. This analysis is based on processed and filtered data which have other known perturbations induced by energetic particle events. In order to obtain truly quiescent dark-current background values for the five-day study intervals centered about several full moon sequences and for the corresponding new moon intervals, the data were further screened so that isolated elements showing spurious or abnormal enhancements could be removed selectively [illegible]. The results demonstrate the presence and wing shape of a lunar signal, induced by atmospherically backscattered UV radiation on the Nimbus IV [illegible] [illegible] sufficiently [illegible] to serve as a source for global nighttime [illegible]. However, these results do suggest this as a potential application for future, more sensitive instruments. (Atmospheric scattering, lunar UV radiances, [illegible].)
J. Geophys. Res., Green, Paper 1C1219

0340 Composition (atomic or molecular)
[illegible]
[illegible]
[illegible]

This paper describes the technical design for a [illegible] [illegible] [illegible] [illegible]

0340 Composition (atomic or molecular)
NITRIC OXIDE DELTA BAND EMISSION IN THE EARTH'S ATMOSPHERE: COMPARISON OF A MEASUREMENT AND A THEORY
David W. Rusch (Laboratory for Atmospheric and Space Physics, University of Colorado, Boulder, Colorado, 80309), William E. Sharp

The altitude dependent emission rate in the δ-bands of nitric oxide has been measured in the Earth's atmosphere at night by a scanning ultraviolet spectrometer. The reaction responsible is the two-body association of nitrogen and oxygen atoms. The measurements reveal a vertical intensity beneath the layer for the δ-band system of 19 R. The horizontal emission rate increases from 10 R at 111 km to 160 R at 150 km. Its data have been analyzed with a one-dimensional, time-dependent, vertical-transport model of all nitrogen photochemistry. The calculated and measured intensities agree if the quenching of $N(^2D)$ by atomic oxygen is near 5×10^{-13} $cm^3 s^{-1}$. The diurnal variation of δ-band emission, $N(^4S)$, and NO densities resulting from model calculations are presented and discussed. (Aeronomy, odd nitrogen, airglow)
J. Geophys. Res., Blue, Paper 1A1354

0350 Diffusion and mixing
PARAMETERIZATION OF LINEAR WAVE CHEMICAL TRANSPORT IN PLANETARY ATMOSPHERES BY EDDY DIFFUSION
Darrell F. Strobel (Geophysical & Plasma Dynamics Branch, Naval Research Laboratory, Washington, D.C. 20375)

Two dimensional transport by linear waves is parameterized by wave coloring and temperature correlations and non-conservative properties of the atmosphere in a residual Eulerian framework. Explicit expressions derived for the eddy tracer flux vector are written to eddy diffusion tensor form, but it is demonstrated that strong coupling of chemistry and temperature through the rate constants, as is the case for ozone, requires additional terms proportional to the mixing ratio and not the gradient. A variety of limiting cases are discussed. In the residual Eulerian framework the K_{yy}, K_{zy} components are non-zero for a non-conservative atmosphere and/or a reactive tracer. Tracers have common transport coefficients in the limit where their chemistry is negligible in comparison to transference. It is shown that the usual 1D vertical eddy diffusion continuity equation is rigorously valid only when the temperature dependence of the rate constants is negligible and the tracer has strong vertical stratification relative to its horizontal variability.
J. Geophys. Res., Green, Paper 1C1184

0440 Convection, diffusion, mixing, turbulence, and fallout
ON THE UPPER ATMOSPHERIC CHEMILUMINESCENT EMISSION OBSERVED UPON RELEASE OF ALUMINUM VAPOR AND ITS COMPOUNDS
J. L. Gole (Department of Chemistry, Georgia Institute of Technology, Atlanta, Georgia 30332) C. E. Kolb

Upper atmospheric chemical releases of aluminum vapor and gaseous aluminum compounds have been used to determine a number of atmospheric properties in the 90–220 km altitude range. Visible radiation from nighttime releases is due to a chemiluminescent reaction which has been traditionally identified as the radiative combination of AlO with atomic oxygen to form electronically excited AlO_2. Atmospheric release data are reviewed which eliminate this traditional mechanism. Results from laboratory experiments are presented which indicate key roles for electronically excited HAlOH formed in a direct insertion reaction of atomic aluminum with water vapor and $AlO^*(A^2\pi)$ formed via the reaction of oxygen atoms with weakly bound aluminum adducts. These new mechanisms significantly influence the nature of input data for atmospheric models.
J. Geophys. Res., Blue, Paper 1A1101

0410 Pressure, density and temperature
INCOHERENT SCATTER RADAR STUDIES OF MESOSPHERIC TEMPERATURES AND COLLISION FREQUENCIES AT ARECIBO
C. A. Tepley (Space Physics Research Laboratory, The University of Michigan, Ann Arbor, Michigan 48109), J. D. Mathews and S. Ganguly

The Arecibo 430 MHz incoherent scatter radar is used to measure the ion-neutral collision frequency and temperature of the atmosphere in the 70 to 100 km altitude range. These parameters are determined over altitude segments which are comparable to the scale height of the mesosphere. The spectra scattered from the mesosphere are collision dominated, that is, for the Arecibo radar frequency, [illegible] at all heights observed. Analysis of the widths of these spectra show that both the temperature and collision frequency values agree quite favorably with the CIRA model atmosphere for the summer months. (Mesospheric temperatures, collision frequencies, incoherent scatter.)
J. Geophys. Res., Blue, Paper 1A1205

0499 General or miscellaneous
THE SOLAR IRRADIANCE FROM 200 TO 310 NM
[illegible] (Laboratory for Planetary Atmospheres, NASA/Goddard Space Flight Center, Greenbelt, MD 20771) J. A. Frederick and [illegible]

The full disk solar spectrum over the wavelength range 200–310 nm has been measured with a spectral resolution of 0.12 nm. The measurement was performed using a double monochromator pointed at the sun from a high altitude platform. Only small corrections were required to account for atmospheric absorption. [illegible] [illegible] [illegible]
J. Geophys. Res., Green, Paper 1C1210

Electromagnetics

0720 Electromagnetic theory
NUMERICAL METHODS FOR ESTABLISHING SOLUTIONS TO THE INVERSE PROBLEM OF ELECTROMAGNETIC INDUCTION
Robert L. Parker (Institute of Geophysics and Planetary Physics, Scripps Institution of Oceanography, University of California, San Diego, La Jolla, California 92093) Kathryn A. Whaler

A previous paper (Parker, 1980) sets out a theory for deciding whether solutions exist to the inverse problem of electromagnetic induction, and outlines methods for constructing conductivity profiles when their existence has been demonstrated. The present paper provides practical algorithms to perform the necessary calculations stably and efficiently, concentrating attention on the case of imprecise observations. The matter of existence is treated by finding the best-fitting solution in a least-squares sense; then the size of the misfit is tested statistically to determine the probability that the value would be met or exceeded by chance. We obtain the optimal solution by solving a constrained least-squares problem linear in the spectral function of the electric-field differential equation. The spectral function is converted into a conductivity profile by transforming its partial fraction representation into a continued fraction, using a stable algorithm due to Rutishauser. In addition to optimal models, which always consist of delta functions, two other types of model are examined. One consists of a finite stack of uniform layers, constructed so that the product of conductivity and thickness-squared is the same in each layer. The numerical technique developed for the optimal model serve with only minor alteration to find solutions in this class. Models of the second kind are smooth. A special form of the response is chosen so that the kernel functions of the Fredholm-Hermitian integral equation are degenerate, thus allowing very stable and numerically efficient solution. Unlike previously published methods for finding conductivity models, these algorithms can provide solutions with misfits arbitrarily close to the smallest one possible. The methods are applied to magnetotelluric observations made by Larsen in Hawaii. (Inverse theory, magnetotellurics).
J. Geophys. Res., Red, Paper 1B1057

0720 Electromagnetic theory
SIMULATION OF A LIGHTNING CHANNEL BY A PROLATE SPHEROID
[illegible] (Radioastronomical Institute, University of Bonn, 53 Bonn, W. Germany)

The channel of a lightning stroke is modelled by an extremely elongated prolate spheroid of moderate electric conductivity. The model simulates return strokes if the center of the spheroid has electrical contact to an electric wall (the Earth's surface). Otherwise, it simulates K streamers. Discharging of an electric charge within each spheroid occurs in an impulsive way due to the wave guide characteristics of the channel. The eigenvalues, eigenfrequencies, and eigenfunctions of electromagnetic fields and currents inside and outside the channel are calculated. They are compared with corresponding values of a cylindrical model. The agreement is reasonable as long as $|\omega l/c| \le 1$ with ω the eigenfrequency, $2l$ the channel length and c the speed of light. Most observed rise times of return strokes and of streaks from return strokes or K streaks meet that condition.
Rad. Sci., Paper 1S1218

0699 Remote sensing
A DECONVOLUTION METHOD FOR PULSED COHERENT RADARS
P. Lehmann (Max-Planck-Institut für Aeronomie, D-3411 Katlenburg-Lindau 3, W. Germany)

The effects of an unavoidably limited transmission and/or reception bandwidth upon a pulsed coherent radar experiment can be partially overcome by the deconvolution method described. Unlike 'conventional' techniques, an accurate knowledge of the radar system pulse response is not required to estimate the propagation delays of reflected pulses (echoes). However, a knowledge of the complex pulse response facilitates the simulation (phase-Cayley) of a 'generalized' echo adaptive model, from which a deconvolution analysis can yield 95% confidence limit estimates for the associated echo delays. Simulation results are presented showing dependence between the errors in delay estimates, the form of pulse response, and deconvolution control parameters.
Rad. Sci., Paper 1S1262

0699 Remote Sensing
INVERSION OF DATA FROM DIFFRACTION-LIMITED MULTIWAVELENGTH REMOTE SENSORS, 1. SCANNING MULTICHANNEL MICROWAVE RADIOMETER DATA
P.W. Rosenkranz (Research Laboratory of Electronics, Massachusetts Institute of Technology, Cambridge, MA 02139)

A spatial filtering algorithm is described, by means of which geophysical parameters are retrieved from measurements made over the ocean by the Scanning Multichannel Microwave Radiometer on the Nimbus-7 satellite. The parameters are near-surface wind speed, sea surface temperature, rain rate, integrated atmospheric water vapor content, and integrated liquid water content (including rain). The capabilities and limitations of the algorithm are demonstrated with data obtained from a tropical cyclone which occurred in the Indian Ocean in November 1978 and with data from the North Atlantic. The major limiting factor, away from land, is the high opacity of the atmosphere in areas of heavy rain, particularly with respect to retrieval of surface temperature and water vapor. However, despite the presence of rain the wind speed retrieval locates the cyclone and provides a measure of its intensity.
Rad. Sci., Paper 1S1204

0699 Remote Sensing
INVERSION OF DATA FROM DIFFRACTION-LIMITED MULTIWAVELENGTH REMOTE SENSORS. 2. NONLINEAR DEPENDENCE OF OBSERVABLES ON THE GEOPHYSICAL PARAMETERS
P. W. Rosenkranz (Research Laboratory of Electronics, Massachusetts Institute of Technology, Cambridge, Massachusetts 02139)

Linear shift-invariant spatial filtering is applied to inversion of radiometric measurements of the earth in both polarizations at frequencies of 6.6, 10.7, 18, 21 and 37 GHz. The state of the ocean-atmosphere system, for the purpose of radiative transfer calculations at these frequencies, is described by a seven-parameter model. The parameters are sea surface temperature, near-surface wind speed, integrated water vapor mass, scale height of water vapor in an exponential distribution, integrated liquid water mass, height of the liquid water and characteristic drop radius in a Deirmendjian drop-size distribution. Nonlinear dependence of brightness temperature on these parameters is approximated by second-order terms in the parameters. Residual nonlinearity of the system appears theoretically as crosstalk from the second-order terms to the first-order terms. Given the linear filter structure, the filter coefficients are obtained by minimizing the expected square error, which includes both first and second order components of crosstalk, noise and finestructure error. The last is the result of incomplete restoration of the geophysical parameter fields. Thus the spatial filter deconvolves and inverts the data simultaneously. The two heights are found not to be retrievable from the measurements, however.
Rad. Sci., Paper 1S1203

Geochemistry

1418 Chemistry of the atmosphere
METHANE FLUX IN FORESTED FRESHWATER SWAMPS OF THE SOUTHEASTERN UNITED STATES
Robert C. Harriss (NASA Langley Research Center, Hampton, Virginia 23665) and Daniel I. Sebacher

Methane emissions to the atmosphere from cypress swamp habitat in four wetland ecosystems of the southeastern United States range from 0.0048 to 0.068 $gCH_4m^{-2}day^{-1}$. The possible causes for this range include differences in nutrient input and organic accumulation. These results indicate that existing data are inadequate to estimate the role of wetlands as a source of methane to the global troposphere. (Methane, freshwater, biosphere).
Geophys. Res. Lett., Paper 1L1314

1410 Chemistry of the atmosphere
THE DIURNAL VARIATION OF NO_3
U. Platt (Institut für Chemie 3: Atmosphärische Chemie, Kernforschungsanlage Jülich GmbH, Postfach 1913, D-5170 Jülich, FRG) D. Perner, J. Schröder, C. Kessler and A. Tönnissen

Spectroscopic observations of the nighttime behaviour of the nitrate radical $[NO_3]$ are presented. The equilibrium constant $K_{eq} = [NO_3][NO_2]/[N_2O_5]$ was determined as $(2.0\pm1)\times10^{10}$ cm^{-3} (at 10°C) in three independent ways.

Maximum concentrations of NO_3 were found to be highly variable. Lifetimes for NO_3 shorter than one minute in the presence of fog indicate a fast reaction of N_2O_5 with liquid water droplets. At relative humidities below 50 % the maximum NO_3 concentrations were still lower than expected from the NO_2–O_3-reaction sequences which must be due to unknown sinks for NO_3 and/or N_2O_5 or to an inadequacy in the presently accepted reaction scheme. (Reactive radicals, NO_x-deposition).
J. Geophys. Res., Green, Paper 1C1180

1410 Chemistry of the atmosphere
GLOBAL ATMOSPHERIC DISTRIBUTION AND TREND OF METHYLCHLOROFORM (CH_3CCl_3)
R. A. Rasmussen and M. A. K. Khalil (Oregon Graduate Center, Beaverton, Oregon 97006)

Over the last two years atmospheric measurements of methylchloroform (CH_3CCl_3) have been made at six locations using EC/GC techniques. The concentrations are reported, and it is shown that CH_3CCl_3 concentrations increased at rates of 3.8±2.1% per year at Alaska (~78°N) between 8/79 and 1/81, 6.8±1.1% per year at Oregon (~45°N) between 1/79 and 1/81, 4.3±2.4% per year at Hawaii (24°N) between 11/79 and 1/81, 4.1±4.8% per year at Samoa (14°S) between 2/80 and 1/81, 11.5±1.5% per year at Tasmania (42°S) between 1/79 and 0/80, and at 6.7±5.7% per year at the south pole between 1/79 and 1/81. These recent yearly increases are smaller than earlier rates of increase but are consistent with a lifetime of ~7 years (6 years–10 years) and a decline in the rate of global emissions. (Atmosphere, concentration, trend, trace gas)
Geophys. Res. Lett., Paper 1L1155

1410 Chemistry of the atmosphere
A TWO-DIMENSIONAL MODEL OF STRATOSPHERIC CHEMISTRY AND TRANSPORT
C. Miller (E. I. du Pont de Nemours & Co., Engg. Dept., E304/C217, Exp. Sta., Wilmington, DE 19898) D. L. Filkin, A. J. Owens, J. M. Steed, and J. P. Jesson

A two-dimensional chemical model of the atmosphere is described. The model includes the major features associated with advanced one-dimensional models: 38 active chemical species and all the chemical reactions connecting them, diurnal effects, and Rayleigh scattering. The species are transported and calculated separately, with the exception of the odd oxygen family [O_3, $O(^3P)$, $O(^1D)$] and H and N atoms. The transport scheme contains both diffusive and advective terms, with the advective circulation field of Murgatroyd and Singleton (appropriately scaled) used to approximate the Lagrangian mean flow.

Comparison of the model predictions with atmospheric observations of long-lived trace species such as O_3, N_2O, CF_2Cl_2, $CFCl_3$, and CH_4 suggests that the transport parameterization gives a good representation of actual trace species motions. For constituents which are more active or whose chemistry is less well known, the model is a useful diagnostic tool for assessing our current understanding of atmospheric chemistry. A number of significant discrepancies between experiment and theory are highlighted, the most important being in the Cl_x and NO_y families.
J. Geophys. Res., Green, Paper 1C1187

1410 Chemistry of the atmosphere
THE LIFETIME OF CARBONYL SULFIDE IN THE TROPOSPHERE
J. E. Johnson (Department of Atmospheric Sciences AK-40, University of Washington, Seattle, Washington 98195, U.S.A.)

Recently revised estimates for the photochemical loss rates of tropospheric OCS indicate that ocean hydrolysis may be the most important sink. A simple air-sea thin film transfer model, coupled with water hydrolysis indicates that the lifetime of tropospheric OCS with respect to this flux has a lower-limit of 11 years, which yields a net lifetime for tropospheric OCS of 4-7 years. (Atmosphere, carbonyl sulfide, air-sea).
Geophys. Res. Lett., Paper 1L1060

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CONTENTS

Geodesy and Gravity

1905 Artificial satellite techniques
ADVANCED SATELLITE SYSTEMS AND THEIR APPLICATIONS
R.J. Anderle (Naval Surface Weapons Center, Dahlgren, Virginia 22448, USA)

The most dramatic advance in gravimetric geodesy since the last IUGG assembly has been achieved through the analysis of radar altimeter observations from the GEOS-3 and SEASAT-1 satellites. The GEOS-3 data has provided the first ever most of the ocean surface, which was inaccessible in significant amount of gravimetric data. The SEASAT-1 satellite data completed the data. The SEASAT-1 satellite data completed the ocean survey to a density of about 0°6 in latitude and longitude or better, and improved the precision of the data. The accuracy of the ocean geoid is estimated to be better than 0.5 m. The NAVSTAR Global Positioning System is expected to provide a major advance in positioning accuracy in the mid 1980's. It is expected that absolute positions of sites to 1 m accuracy and relative positions of sites to a few cm accuracy will be obtained in a few hours of time on site.
manuscripta geodaetica Vol.5, No.1, 1980

1910 Crustal movements
GEODETIC MEASUREMENT OF CRUSTAL DEFORMATION ON THE SAN ANDREAS, HAYWARD AND CALAVERAS FAULTS NEAR SAN FRANCISCO, CALIFORNIA
W.H. Prescott (U. S Geological Survey, 345 Middlefield Road, Menlo Park, California 94025) M. Lisowski and J.C. Savage

Analysis of a geodetic network of 115 lines crossing the San Andreas, Hayward and Calaveras faults in the vicinity of San Francisco Bay, measured repeatedly between 1970 and 1980, has revealed details about the accommodation of relative plate motion in this area. The most striking result is that the deformation is not uniformly distributed across the area. In the east bay along the Hayward and Calaveras faults all motion appears to take place as slip directly on the fault with no accumulation of strain in the adjacent crust. On both the Calaveras and the Hayward faults the rate obtained for the 1970 to 1980 period agrees with geologic rates spanning a few million years and with creep rates spanning a few decades. The Hayward fault slip rate is 7 ± 1 mm/a. The Calaveras fault slip rate is 17 ± 1 mm/a with perhaps half of this slip distributed across a zone a few kilometers wide, probably as inelastic deformation of weak near surface material. The absence of strain accumulation in the east bay is surprising since the Hayward and Calaveras faults have been the site of large earthquakes in the past. A block located east of the Calaveras fault and south of the San Andreas fault has been rotating clockwise at a rate of 0.1 ± 0.1 μrad/a with very little internal deformation. Along the San Francisco peninsula no detectable slip occurs (less than 1.5 mm/a) at the surface but appreciable strain is accumulating. Near fault shear strain rates are 0.6 ± 0.1 μstrain/a (engineering) with direction N47°W ± 5. The slip rate near the San Andreas fault is 12.2 ± 3.9 mm/a, distributed across a broad zone. The relative motion across the whole region during the period 1970–1980 is 32.1 ± 7.4 mm/a.
J. Geophys. Res., Red, Paper 1B1250

1920 Geometric observations and methods
A STATISTICAL DETECTION METHOD APPLIED TO DETECTION AND REJECTION OF ERRONEOUS OBSERVATIONS
I. Cleric, H.U. Harris (University of Queensland, Dept. of Surveying, St. Lucia, Qld. 4067, Australia)

The paper discusses a statistical theory for detection of outliers in observations and for assessment of their reliability. Contrary to traditional approach of testing based on probabilities of making errors type 1 and 2, this approach is based directly on the influence the rejection criterion would have on the estimated parameters. A photogrammetric example is used to illustrate the application of the theory. Comparison with the theory of Baarda based on this experiment yields essentially identical results. No theoretical link of the two approaches has however been attempted.
manuscripta geodaetica Vol.5, No.4, 1980

1930 High-order harmonics of the gravity potential field and local gravity anomalies
ELLIPSOIDAL CORRECTIONS FOR GEOID COMPUTATIONS
R.H. Rapp (Dept. of Geodetic Science, The Ohio State University, Columbus, Ohio 43210)

Ellipsoidal correction terms have been derived for geoid undulation computations when the Stokes equation using gravity anomalies in a cap is combined with potential coefficient information. The correction terms are long wavelength and depend on the cap size in which the gravity anomalies are given. Using the regular Stokes equation the maximum correction for a cap size of 20° is -41 cm which reduces to -27 cm when the Stokes function is modified by subtracting the value of the Stokes function at the cap radius. Ellipsoidal correction terms were also derived for the well known Marsh/Chang geoids. When a gravity was used the correction could reach 70 cm, while for a cap size of 20° the maximum correction was -45 cm.

Global correction maps are given for a number of different cases. For work requiring accurate geoid computations these correction terms should be applied.
J. Geophys. Res., Red, Paper 1B1282

1930 High-order harmonics of the gravity potential field and local gravity anomalies
A PRACTICAL COMPARISON OF SOME METHODS OF PREDICTING POINT GRAVITY ANOMALIES
F.L. Merry (Dept. of Surveying, University of Cape Town, Rondebosch, South Africa)

Point gravity anomalies are required for a number of purposes in geodesy. In many instances these must be predicted from non-uniformly distributed observations. In this paper, three different methods for this prediction are compared, using test data from two dissimilar regions of Southern Africa. These methods are:
(a) graphical interpolation from anomaly contours,
(b) least-squares surface fitting,
(c) least-squares estimation, using a local covariance function.

Of these methods graphical interpolation is found to be unreliable in regions of sparse data. Both least-squares methods provide results of similar accuracy with the RMS error ranging from 1mgal in areas of dense data, to 7mgal in mountainous areas with sparse data. However, the surface-fitting technique is limited in regions of poor spatial distribution of the data, and cannot be used for extrapolation. Least-squares estimation does not have these limitations, and is the preferable method.
manuscripta geodaetica, Vol.5, No.4, 1980

1935 Low-order harmonics of the gravity potential field
THE SIMILARITY TRANSFORMATION OF THE GRAVITATIONAL POTENTIAL CLOSE TO THE IDENTITY
A. Sterberg (Geodätisches Institut der Universität Stuttgart, Keplerstraße 11, D-7000 Stuttgart 1, FRG)

The transformation properties of the gravitational potential represented by spherical harmonics due to variations of type translation, rotation and scale are investigated. The similarity transformation is used close to the identity. It is proved that in linear approximation (1) scale and rotational variations leave spherical harmonics of order m to spherical harmonics of order m-1, m and m+1 and not affect the degree, but (ii) that a translation transforms spherical harmonics of degree ℓ into spherical harmonics of degree ℓ and ℓ±1. Geodetic examples are given. Rotational variation due to diurnal polar motion, translational variation due to origin shift and scale variation of the underlying coordinate system.
manuscripta geodaetica Vol.5, No.4, 1980

1935 Low-order harmonics of the gravity potential field
THE TWO-DIMENSIONAL GEODETIC BOUNDARY VALUE PROBLEM
P. Geronlopoulos (154 Patission Street, Athens 803, Greece)

The geodetic boundary value problem is defined and subsequently attacked in a two-dimensional model. Complex analytic methods and conformal mapping techniques are used for treating the problem algorithmically. The various approximations made in the three-dimensional case are formulated in the plane model and the problem is reduced to equivalent singular integral equations.
manuscripta geodaetica, Vol.6, No.1, 1981

1935 Low-order harmonics of the gravity potential field
THE SPACELIKE MOLODENSKY PROBLEM INCLUDING THE ROTATIONAL TERM OF THE GRAVITY POTENTIAL
A. Bode (University FAF at Munich, Werner Heisenberg Weg 39, D-8014 Neubiberg, Germany, Fed. Rep.)
E.W. Grafarend (Dept. of Geodetic Science, Stuttgart University, Keplerstraße 11, PO Box 560, D-7000 Stuttgart 1, Germany, Fed. Rep.)

The linearized boundary operator of the geodetic boundary value problem is derived for a normal potential including a term of the centrifugal potential. The linearized boundary operator is rigorously computed leading beside a derivative with respect to the spherical coordinate radius r to an additional derivative with respect to the spherical coordinate latitude ɸ. The linearized geodetic boundary value problem is rigorously solved by the Hilbert space method, e.g. a spherical harmonic representation of the unknown disturbing potential and the known gravity anomaly. A base representation of the infinite dimensional system of equations is achieved by using recurrence relations of spherical harmonics and Wigner 3j-coefficients. The solution of the system of equations is constructed by a Neumann series whose convergence is proved by a theorem of the mathematical fix point theory. It becomes obvious that the solution can be represented by a generalized Stokes function which beside the spherical distance depends upon the azimuth of a great circle connecting two points projected onto the unit sphere.
manuscripta geodaetica, Vol.6, No.1, 1981

1950 Relations of gravity observations to tectonics and isostasy
THE DARFUR SWELL, AFRICA: GRAVITY CONSTRAINTS ON ITS ISOSTATIC COMPENSATION
S.T. Crough (Department of Geosciences, Purdue University, West Lafayette, Indiana 47907)

The free-air gravity anomaly observed over the Darfur Swell is explainable by local isostatic balance with a root approximately 50 km deep on average. This root depth is similar to that inferred beneath other African domes and beneath oceanic midplate swells, suggesting that the Darfur Swell is a hotspot uplift created by lithospheric reheating. (Gravity, swell, [illegible])
Geophys. Res. Lett., Paper 1L1085

1980 Tides
DISSIPATION DUE TO OBLIQUITY INDUCED TIDES IN A KELVIN-VOIGT VISCOELASTIC BODY
V. S. VanAradale (Department of Mechanical Engineering, University of Houston, Houston, TX 77004)

The local and total dissipation rate of mechanical energy is calculated for an incompressible, Kelvin-Voigt body in a circular orbit with finite obliquity. This material is characterized by a shear modulus and a viscosity. While in principle both of these material constants could be determined experimentally, only the shear modulus is known. The variation of the total dissipation rate with the viscosity is studied. For 'small' values of the viscosity, the Kelvin-Voigt material approximates the behavior of an elastic solid. In this range, results for the Earth-Moon system are similar to those obtained by Peale and Cassen (Icarus, 36, 255–269, 1978) using a modified form of the elastic solution. For 'large' values of the viscosity, the results are qualitatively different from those in the 'elastic' range as viscous effects dominate the material response. (Tidal dissipation, viscoelasticity)
J. Geophys. Res., Red, Paper 1B1275

1990 Instruments and techniques
THEORIE DU GYROCOMPAS SUSPENDU
I. EQUATIONS DU MOUVEMENT
L.H.A. Jaudy (Département de Géodésie et de Cartographie, Faculté de Foresterie et Géodésie, Université Laval, Ste. Foy, Quebec G1K 7P4, Canada)

For several decades, the suspended gyrocompass is one of the most frequently used gyroscopic system for the Astronomical North determination. Previous to 1975, the existing theory (Beimel, 1950) is very approximate since it does not take into account the fact that the gyroscope is enclosed in a carter suspended by a very tenuous tape. In more recent works, the existing theory has been utilized (Grafarend, 1967), (Vaníček, 1972). Still it does not explain the motion of the axis of the gyroscope satisfactorily because one can easily observe a wobble of a period of about 1° superimposed to the principal oscillation and this is not predicted by the existing theory at that time. In an unpublished document, Vaníček proposes to modelize this wobble by a damped sine function. In 1975 a more precise theory is developed taking into account the fact that the gyroscope is suspended (Schultz, 1975). Nevertheless, Coriolis forces are neglected in some places (Schultz, 1975; p.39) and the consequence is that such a theory is not precise enough for geodetic purposes. Nowadays, the increased precision of measurements (Halmos, 1977) necessitates the elaboration of a rigorous theory as developed here. We are effectively taking into account the foci that the gyroscope is suspended. No forces are neglected and slight approximation not affecting more than five units of the ninth digit is made for the centrifugal forces due to the earth rotation. The consequence, as in (Schultz, 1975), is that we have a system with five degrees of freedom (two coordinates for the downward extremity of the tape fixed to the carter, point I of fig.2, and the three Euler angles defining the position of the carter, unlike Schultz who is using [illegible] (in addition to the so called Cardan angles). In addition to the so called Euler equations, we derive new equations in order to determine completely the five parameters of position indicated above. Unlike Schultz, we do not perform linearization at that stage.
manuscripta geodaetica, Vol.6, No.1, 1981

1990 Instruments and techniques
THE USE OF THE LASER INTERFEROMETER FOR SCALE CALIBRATION OF THE NOTTINGHAM BASELINE
A.H. Dodson, C.P. Death, V. Ashkenazi (Department of Civil Engineering, University of Nottingham, Nottingham, U.K.)

The Laser Interferometer system, which was adopted at Nottingham to scale the calibration baseline, has several advantages over the Väisälä comparator, but leads to somewhat lower accuracies. It is more flexible, less time consuming and less expensive. Initial problems with the mechanical accuracy of the centring and measuring system have been solved, and the potential of the interferometer for high precision realised, reducing the repeatability of the centring to ± 0.003 mm. This, coupled with a meteorological sensing system calibrated to ± 0.1 parts-per-million, enables the Nottingham baseline to be calibrated to within ± 0.6 ppm.
manuscripta geodaetica, Vol. 6, No.1, 1981

Izvestiya Physics of the Solid Earth
Volume 16, Number 3

CONTENTS

Geomagnetism and Paleomagnetism

2530 Spatial variations
A CLOSER EXAMINATION OF THE REDUCTION SATELLITE MAGNETOMETER DATA FOR GEOLOGICAL STUDIES
R. Regan (Phoenix Corporation, 1700 Old Meadow Road, McLean, Virginia 22102) B. Handschumacher and N. Sugiura

Global and regional studies of the data abstracted from the Pogo satellites have demonstrated the utility of satellite magnetometer measurements in geological studies. However, detailed examination of these data reveals that there exists a considerable amount of noise resulting from external fields and data reduction techniques. Such noise inhibits more detailed studies with the Pogo data and could similarly affect the utility of data from the Magsat mission. Correlation of Pogo satellite data with ground observatory records and geomagnetic indices, was employed to identify the existence of external field effects and document the data reduction problems. Significant effects of the Sq current system, including the equatorial electrojet, are shown to be still in the data despite the local time screening. Such effects are totally in agreement with theoretical models of this current system and should be considered in Magsat data reduction as the theoretical model predicts that the Sq current may at times have significant effects even at the dawn/dusk local times of the Magsat orbit. The state of inflation and deflation of the magnetosphere is vividly portrayed in the Pogo measurements and well correlated with the Dst index. The ring current correction applied to the Pogo data was seen to be of varying quality depending upon the state of the magnetosphere and the length of satellite track data reduced. These effects combined with the irregular distribution of data from the individual Pogo satellites can result in pseudo anomalies as evidenced by a comparison of satellite data reduced in a fashion to minimize them with those previously published over the same area.
J. Geophys. Res., Red, Paper 1B1175

2560 Time variations, paleomagnetism
PALEOMAGNETISM OF THE LATE ORDOVICIAN NEDA IRON ORE FROM WISCONSIN, IOWA AND ILLINOIS
William F. Kean (Department of Geological Sciences, University of Wisconsin-Milwaukee, Milwaukee, WI. 53201)

The Neda Iron Formation (Late Ordovician) is a hematite and goethite rich oolitic ore which occurs in lens shaped deposits on top of the Maquoketa shale (Late Ordovician), at only a few locations in Wisconsin, Iowa and Illinois. Thermal demagnetization of samples from these three states, indicates the remanence is carried by hematite. Chemical demagnetization suggests the remanence is produced by the interstitial material rather than the oolites.

The paleopole averaged for all sites from 11 samples of the Neda are is at 045.8°, W48° (α95 = 18°). This pole position is similar to late Mississippian to early Permian of North America rather than latest Ordovician. The difference between the known age of the Neda and the time of magnetization suggests that the hematite in the ore was produced from dehydration of goethite probably as a result of tectonic uplift in Wisconsin during late Mississippian time. In addition, these results add evidence to the theory that the Neda ore was formed in two stages. The oolites were produced in a near shore environment during the shoaling of the Ordovician seas. The oolites were then incorporated in iron rich muds. Burial and later uplift dehydrated the iron hydroxide to hematite.
Geophys. Res. Lett., Paper 1L1822

Hydrology

3110 Groundwater
METHODS OF CONFINING OIL IN UNLINED CAVERNS IN AQUIFERS: WATER TABLE MAINTENANCE BY WELL RECHARGE
R. Thunvik, C. Braester (Technion - The Israel Institute of Technology, Haifa, Israel).

A major problem in unlined caverns located in aquifers is maintenance of the water table at a prescribed level, thus preventing migration of oil. In order to maintain a prescribed constant level it is necessary, in most cases, to inject water into aquifer.

The influence of rock properties and of the flow geometry on the rates of water flow into the cavern and on the shape of the phreatic surface were studied. The equations of flow were solved by a numerical method and the results were presented in a dimensionless form.

Some conclusions achieved from the analysis of the results are (i) the rate of water flow into the cavern increases approximately linearly with the depth of the cavern roof below the constant level in the injection wells (ii) to confine the oil in the cavern, the injection wells should be located at a distance from the cavern centerline, less than $L_D = 5$, for a depth of the cavern roof $H_{TO} = 1.74$ below the constant water level in the wells. The dimensionless length L_D and depth H_{TD} are defined as ratios to half width of cavern (oil storage, phreatic surface).
Water Resour. Res., Paper 1W1086

3130 Groundwater
AN ALTERNATIVE DEVELOPMENT OF THE DISPERSION EQUATION
H.Roerjadi (Delft University of Technology, Dept. of Civil Engineering)

Dispersion of particles is governed by a differential equation, which has been derived in 1972 by De Josselin de Jong using a so-called canal model (introduced by himself in 1957 for the computation of the spreading of salt by groundwater flowing through porous media). This is another mathematical approach based upon the same model. (Dispersion, equation, particles, stochastical approach).
Water Resour. Res., Paper 1W0991

3130 Groundwater
ON THE COMPUTATION OF DARCIAN VELOCITY AND MASS BALANCE IN THE FINITE-ELEMENT MODELING OF GROUNDWATER FLOW
G. T. Yeh (Oak Ridge National Laboratory, Oak Ridge, Tennessee)

Darcian velocity has been conventionally calculated in the finite element modeling of groundwater flow by taking the derivatives of the computed pressure field. This results in discontinuities in the velocity field at nodal points and element boundaries. Discontinuities become enormous when the computed pressure field is far from a linear distribution. It is proposed in this paper that the finite element procedure that is used to simulate the pressure field or the moisture-content field also be applied to Darcy's law with the derivatives of the computed pressure field as the load function. The problem of discontinuity is then eliminated, and the error of mass balance over the region of interest is much reduced. The reduction is from 21.6 to 2.2% by one numerical scheme and from 29.7 to -3.6% by another for a transient problem. (Groundwater flow, finite-element modelling, saturated-unsaturated porous media).
Water Resour. Res., Paper 1W1189

3130 Groundwater
TWO-PHASE FLOW SIMULATION OF AIR STORAGE IN AN AQUIFER
David Petri (MUS Corporation, Environmental Systems Group, 1 Research Place, Rockville, MD 20850)

A two-phase flow model is presented for simulating air storage in an aquifer used for a compressed air storage system. The governing equations describing the flow of air and water are coupled nonlinear partial differential equations and are solved by a Galerkin finite element method. The resulting computer model is used to simulate the air-water displacement in a one-dimensional storage reservoir during daily air cycling the corresponding saturation and pressure variations, and the effects of reservoir [illegible] on the system are presented. The results obtained realistically describe a variable-volume storage system with only a small change in pressure. (Aquifer, compressed air storage, finite elements, two-phase flow)
Water Resour. Res., Paper 1W1114

3145 Limnology
DETERMINATION OF CHARACTERISTIC VALUES FOR PHYSICAL AND CHEMICAL LAKE SEDIMENT PARAMETERS
L. Håkanson (National Swedish Environment Protection Board, Box 8041, 750 08 Uppsala, Sweden)

The aim of the present work has been to discuss how characteristic values can be determined for physical and chemical sediment parameters in lakes. It is shown that various physical sediment parameters, e.g. water content, bulk density, organic content, grain size, degree of compaction, and sediment depth, may be related to each other and especially to the water content of the sediments, which may be considered as a key parameter in this context.

It is demonstrated that the areal distribution of these physical parameters may be described by the following general formula:

$$Ph_{0-1} = Ph_{\ddot{a}} - K_L \cdot \frac{100 - D_0}{D_p \cdot K_L \cdot K_{Ph}}$$

where Ph_{0-1} is the given physical sediment parameter from the layer 0 – 1 cm, $Ph_{\ddot{a}}$ is the characteristic content of the parameter in the given lake/basin, K_L is an empirical lake constant, K_{Ph} is a parameter constant and D_p is the relative water depth (D_p = 100 % for the maximum depth).

The validity of this relationship is illustrated for five Swedish lakes (Hjälmaren, Vänern, northern Vättern, western Mälaren and Ekoln). The relationship is important since it provides a means for prognosis and determination of physically relevant, characteristic values, and not just traditional statistical values, such as various types of means. It is demonstrated: (i) that the distribution of physical sediment parameters depends on the water depth (the relative water depth), (ii) that the spread (standard deviation) around the mean is large in shallow waters, where erosion, transportation as well as accumulation of fine sediments may appear, (iii) that the spread decreases with increasing water depth, and (iv) that the spread is relatively small at all water depths within the zone of accumulation. This allows the determination of a characteristic value at D_p = 100 % (D_{max}). This argument will only be valid in lakes with areas of accumulation.

The "critical" water content (W_{T-A}) separating areas of accumulation from zones of transportation may be estimated from the relationship $W_{T-A} = W_{\ddot{a}} - 10$, where $W_{\ddot{a}}$ is the characteristic water content.

Characteristic values may be determined in a similar manner for chemical parameters showing a high correlation with the water content, i.e. naturally non-contaminating parameters.

For contaminating substances, which are distributed in a typical way in lake sediments in the form of distinct tongues with decreasing concentrations with distance from the polluting source, characteristic values cannot be determined with the mentioned method. However, for contaminating substances, like mercury in the investigated lakes, characteristic values may be determined from the map illustrating the areal distribution pattern, at the areal median value. (Lake sediments, model, spatial variation, lake typical values).
Water Resour. Res., Paper 1W0981

3160 Runoff and streamflow
A DECOMPOSITION METHOD FOR THE LONG-TERM SCHEDULING OF RESERVOIRS IN SERIES
André Turgeon (Hydro-Québec, Varennes, Québec, Canada J0L 2P0)

This paper presents a method for determining the weekly operating policy of a power system of n reservoirs in series; the method takes into account the stochasticity of the river flows. The method consists of rewriting the stochastic nonlinear optimization problem of n state variables as n-1 problems of two state variables which are solved by dynamic programming. The release policy obtained with this method for reservoir i is a function of the water content of that reservoir and of the total amount of potential energy stored in the downstream reservoirs. The method is applied to a power system of four reservoirs and the results obtained are compared to the true optimum. (Multireservoir operation, stochastic, decomposition, dynamic programming)
Water Resour. Res., Paper 1W1196